Claims

What is claimed is:

1. An apparatus for radially expanding and plastically deforming an expandable tubular member, comprising:

an expansion device movable in the expandable tubular member for radially expanding and plastically deforming the expandable tubular member;

a vibratory device coupled to the expansion device for generating vibratory energy to agitate at least one of the expandable tubular member and the expansion device; and

an actuator device coupled to the expansion device for displacing the expansion device relative to the expandable tubular member.

2. The apparatus of claim 1, wherein the expansion device comprises:

a tapered expansion cone.

3. The apparatus of claim 2, wherein the expansion device further comprises:

a locking device coupled to the actuator for fixing the position of the expandable tubular member relative to the actuator during the axial displacement of the expansion cone relative to the expandable tubular member.

4. The apparatus of claim 1, wherein the expansion device comprises:

a rotary expansion device.

5. The apparatus of claim 1, wherein the vibratory device is positioned within a non-expanded portion of the expandable tubular member.

6. The apparatus of claim 1, wherein the vibratory device is positioned within an expanded portion of the expandable tubular member.

7. The apparatus of claim 1, wherein the vibratory device is positioned within the expansion device.

8. The apparatus of claim 1, wherein the vibratory device comprises a plurality of vibratory devices.

9. The apparatus of claim 8, wherein at least one of the vibratory devices is positioned within a non-expanded portion of the expandable tubular member.

10. The apparatus of claim 9, wherein at least another one of the vibratory devices is positioned within an expanded portion of the expandable tubular member.

11. The apparatus of claim 9, wherein at least another one of the vibratory devices is positioned within the expansion device.

12. The apparatus of claim 10, wherein at least another one of the vibratory devices is positioned within the expansion device.

13. The apparatus of claim 8, wherein at least one of the vibratory devices is positioned within an expanded portion of the expandable tubular member.

14. The apparatus of claim 13, wherein at least another one of the vibratory devices is positioned within the expansion device.

15. The apparatus of claim 8, wherein at least another one of the vibratory devices is positioned within the expansion device.

16. The apparatus of claim 1, wherein the vibratory device comprises:
a fluid powered vibratory device.

17. The apparatus of claim 1, wherein the vibratory energy comprises:
vibratory energy in one or more planes.

18. The apparatus of claim 17, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having one or more center frequencies.

19. The apparatus of claim 18, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having a plurality of center frequencies.

20. The apparatus of claim 17, wherein the vibratory energy comprises:
vibratory energy in a plurality of planes.

21. The apparatus of claim 20, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having one or more center frequencies.

22. The apparatus of claim 21, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having a plurality of center frequencies.

23. The apparatus of claim 1, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having one or more center frequencies.

24. The apparatus of claim 23, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having a plurality of center frequencies.

25. The apparatus of claim 1, wherein the magnitude of the vibratory energy is variable.

26. The apparatus of claim 1, wherein the magnitude of the vibratory energy is constant.

27. The apparatus of claim 1, wherein the plane of the vibratory energy is variable.

28. The apparatus of claim 1, wherein the plane of the vibratory energy is constant.

29. The apparatus of claim 1, wherein the expandable tubular member comprises a welbore casing.

30. The apparatus of claim 1, wherein the expandable tubular member comprises a pipeline.

31. The apparatus of claim 1, wherein the expandable tubular member comprises a structural support.

32. The apparatus of claim 1, further comprising:

a vibratory device coupled to the expansion device for generating vibratory energy to impart rotation to the expansion device.

33. The apparatus of claim 1, wherein the vibratory device is adapted to impact the expandable tubular member.

34. The apparatus of claim 1, wherein the vibratory device is adapted to impact the expansion device.

35. The apparatus of claim 1, wherein the expansion device comprises one or more external arcuate spherical surfaces.

36. The apparatus of claim 1, wherein the expansion device comprises one or more external arcuate elliptical surfaces.

37. The apparatus of claim 1, wherein the expansion device comprises one or more external arcuate hyperbolic surfaces.

38. The apparatus of claim 1, wherein the expansion device comprises one or more external arcuate surfaces that are faceted.

39. The apparatus of claim 1, wherein the expansion device comprises a rotary expansion device.

40. The apparatus of claim 1, wherein the vibratory device is positioned within an expanded portion of the expandable tubular member.

41. The apparatus of claim 1, wherein the vibratory device is positioned within the expansion device.

42. The apparatus of claim 1, wherein the vibratory device comprises a plurality of vibratory devices.

43. The apparatus of claim 1, wherein the vibratory energy comprises vibratory energy having a frequency distribution having a plurality of center frequencies; and wherein the vibratory energy comprises vibratory energy in a plurality of planes.

44. The apparatus of claim 1, wherein the vibratory energy has a center frequency of about 40 Hz.

45. The apparatus of claim 1, wherein the expansion device further comprises:

a locking device coupled to the actuator for fixing the position of the expandable tubular member relative to the actuator during the axial displacement of the expansion cone relative to the expandable tubular member.

46. The apparatus of claim 1, wherein the vibratory energy comprises vibratory energy in a plurality of planes; wherein one of the planes is radial; and wherein another one of the planes is longitudinal.

47. The apparatus of claim 1, wherein the vibratory device coupled to the expansion device generates vibratory energy to agitate the expandable tubular member and the expansion device.

48. A method of radially expanding and plastically deforming an expandable tubular member, comprising:

radially expanding and plastically deforming the expandable tubular member using an expansion device;

injecting vibratory energy into at least one of the expandable tubular member and the expansion device; and

displacing the expansion device relative to the expandable tubular member during the radial expansion and plastic deformation of the tubular member using an actuator coupled to the expansion device.

49. The method of claim 48, further comprising:

fixing the position of the expandable tubular member relative to the expansion device during the axial displacement of the expansion device relative to the expandable tubular member.

50. The method of claim 48, further comprising:

rotating the expansion device during the radial expansion and plastic deformation of the expandable tubular member.

51. The method of claim 48, wherein the vibratory energy is injected from a location within a non-expanded portion of the expandable tubular member.

52. The method of claim 48, wherein the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

53. The method of claim 48, wherein the vibratory energy is injected from a location within the expansion device.

54. The method of claim 48, wherein the vibratory energy is injected from a plurality of locations.

55. The method of claim 54, wherein at least some portion of the vibratory energy is injected from a location within a non-expanded portion of the expandable tubular member.

56. The method of claim 55, wherein at least another portion of the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

57. The method of claim 55, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

58. The method of claim 56, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

59. The method of claim 54, wherein at least some portion of the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

60. The method of claim 59, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

61. The method of claim 54, wherein at least a portion of the vibratory energy is injected from a location within the expansion device.

62. The method of claim 48, wherein injecting vibratory energy into at least one of the expandable tubular member and the expansion device comprises:

injecting fluidic materials into the expandable tubular member.

63. The method of claim 48, wherein the vibratory energy comprises:

vibratory energy in one or more planes.

64. The method of claim 63, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having one or more center frequencies.

65. The method of claim 64, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having a plurality of center frequencies.

66. The method of claim 63, wherein the vibratory energy comprises:

vibratory energy in a plurality of planes.

67. The method of claim 66, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having one or more center frequencies.

68. The method of claim 67, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having a plurality of center frequencies.

69. The method of claim 48, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having one or more center frequencies.

70. The method of claim 69, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having a plurality of center frequencies.

71. The method of claim 48, wherein the magnitude of the vibratory energy is variable.

72. The method of claim 48, wherein the magnitude of the vibratory energy is constant.

73. The method of claim 48, wherein the plane of the vibratory energy is variable.

74. The method of claim 48, wherein the plane of the vibratory energy is constant.

75. The method of claim 48, wherein the expandable tubular member comprises a welbore casing.

76. The method of claim 48, wherein the expandable tubular member comprises a pipeline.

77. The method of claim 48, wherein the expandable tubular member comprises a structural support.

78. The method of claim 48, further comprising:
injecting vibratory energy into the expandable tubular member and the expansion device.

79. The method of claim 48, further comprising:
injecting vibratory energy into the expansion device to impart rotation to the expansion device.

80. The method of claim 48, wherein injecting vibratory energy into at least one of the expandable tubular member and the expansion device, comprises:
impacting the expandable tubular member.

81. The method of claim 48, wherein injecting vibratory energy into at least one of the expandable tubular member and the expansion device, comprises:
impacting the expansion device.

82. The method of claim 48, further comprising:
inserting the expansion device and the expandable tubular member into a preexisting structure; and
injecting vibratory energy into at least one of the expandable tubular member and the expansion device during the insertion.

83. The method of claim 48, further comprising:

removing the expansion device and the expandable tubular member from a preexisting structure; and

injecting vibratory energy into at least one of the expandable tubular member and the expansion device during the removal.

84. The method of claim 48, wherein the expansion device comprises one or more external arcuate spherical surfaces.

85. The method of claim 48, wherein the expansion device comprises one or more external arcuate elliptical surfaces.

86. The method of claim 48, wherein the expansion device comprises one or more external arcuate hyperbolic surfaces.

87. The method of claim 48, wherein the expansion device comprises one or more external arcuate surfaces that are faceted.

88. The method of claim 48, further comprising:

radially expanding and plastically deforming the expandable tubular member by rotating an expansion device within the expandable tubular member.

89. The method of claim 48, further comprising:

injecting vibratory energy into at least one of the expandable tubular member and the expansion device from a location within the radially expanded and plastically deformed portion of the expandable tubular member.

90. The method of claim 48, further comprising:

injecting vibratory energy into at least one of the expandable tubular member and the expansion device from a location within the expansion device.

91. The method of claim 48, further comprising:

injecting vibratory energy into at least one of the expandable tubular member and the expansion device from a plurality of discrete spaced apart locations.

92. The method of claim 48, wherein the vibratory energy comprises vibratory energy having a frequency distribution having a plurality of center frequencies; and wherein the vibratory energy comprises vibratory energy in a plurality of planes.

93. The method of claim 48, wherein the vibratory energy has a center frequency of about 40 Hz.

94. The method of claim 48, further comprising:

injecting vibratory energy into expansion device to impart rotation to the expansion device.

95. The method of claim 48, further comprising:

increasing the plasticity and formability of the expandable tubular before the radial expansion and plastic deformation of the expandable tubular member.

96. The method of claim 48, further comprising:

increasing the plasticity and formability of the expandable tubular during the radial expansion and plastic deformation of the expandable tubular member.

97. The method of claim 48, further comprising:

injecting vibratory energy into one or more of the expansion device and the expandable tubular member, wherein the injected vibratory energy is provided in an initial plane, has an initial center frequency, and has an initial amplitude; and

during the radial expansion and plastic deformation of the expandable tubular member:

a) incrementing at least one of the plane, center frequency, and amplitude for the injected vibratory energy;

b) monitoring the amount of energy required to continue the radial expansion and plastic deformation of the expandable tubular member; and

c) repeating steps a) and b) until the completion of the radial expansion and plastic deformation of the expandable tubular member.

98. The method of claim 48, further comprising:

injecting vibratory energy into one or more of the expansion device and the expandable tubular member, wherein the injected vibratory energy is provided in an initial

plane, has an initial center frequency, and has an initial amplitude; and

during the radial expansion and plastic deformation of the expandable tubular member:

a) incrementing two or more of the plane, center frequency, and amplitude for the injected vibratory energy;

b) monitoring the amount of energy required to continue the radial expansion and plastic deformation of the expandable tubular member; and

c) repeating steps a) and b) until the completion of the radial expansion and plastic deformation of the expandable tubular member.

99. The method of claim 48, wherein injecting vibratory energy into at least one of the expandable tubular member and the expansion device comprises injecting fluidic materials into the expandable tubular member.

100. The method of claim 48, wherein the vibratory energy comprises vibratory energy in a plurality of planes; and wherein the vibratory energy comprises vibratory energy having a frequency distribution having one or more center frequencies.

101. The method of claim 48, wherein the expandable tubular member comprises a wellbore casing.

102. The method of claim 48, wherein the expandable tubular member comprises a pipeline.

103. The method of claim 48, wherein the vibratory energy comprises vibratory energy in a plurality of planes; wherein one of the planes is radial; and wherein another one of the planes is longitudinal.

104. A system for radially expanding and plastically deforming an expandable tubular member, comprising:

means for radially expanding and plastically deforming the expandable tubular member using an expansion device;

means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device; and

actuator means for displacing the expansion device relative to the expandable tubular member during the radial expansion and plastic deformation of the expandable tubular member.

105. The system of claim 104, further comprising:

means for fixing the position of the expandable tubular member relative to the means for displacing the expansion device during the axial displacement of the expansion device relative to the expandable tubular member.

106. The system of claim 104, further comprising:

means for rotating the expansion device during the radial expansion and plastic deformation of the expandable tubular member.

107. The system of claim 104, wherein the vibratory energy is injected from a location within a non-expanded portion of the expandable tubular member.

108. The system of claim 104, wherein the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

109. The system of claim 104, wherein the vibratory energy is injected for a location within the expansion device.

110. The system of claim 104, wherein the vibratory energy is injected from a plurality of locations.

111. The system of claim 110, wherein at least some portion of the vibratory energy is injected from a location within a non-expanded portion of the expandable tubular member.

112. The system of claim 111, wherein at least another portion of the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

113. The system of claim 111, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

114. The system of claim 112, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

115. The system of claim 110, wherein at least some portion of the vibratory energy is injected from a location within an expanded portion of the expandable tubular member.

116. The system of claim 115, wherein at least another portion of the vibratory energy is injected from a location within the expansion device.

117. The system of claim 110, wherein at least a portion of the vibratory energy is injected from a location within the expansion device.

118. The system of claim 104, wherein injecting vibratory energy into at least one of the expandable tubular member and the expansion device comprises:

injecting fluidic materials into the expandable tubular member.

119. The system of claim 104, wherein the vibratory energy comprises:

vibratory energy in one or more planes.

120. The system of claim 119, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having one or more center frequencies.

121. The system of claim 120, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having a plurality of center frequencies.

122. The system of claim 119, wherein the vibratory energy comprises:

vibratory energy in a plurality of planes.

123. The system of claim 122, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having one or more center frequencies.

124. The system of claim 123, wherein the vibratory energy comprises:

vibratory energy having a frequency distribution having a plurality of center frequencies.

125. The system of claim 104, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having one or more center frequencies.

126. The system of claim 125, wherein the vibratory energy comprises:
vibratory energy having a frequency distribution having a plurality of center frequencies.

127. The system of claim 104, wherein the magnitude of the vibratory energy is variable.

128. The system of claim 104, wherein the magnitude of the vibratory energy is constant.

129. The system of claim 104, wherein the plane of the vibratory energy is variable.

130. The system of claim 104, wherein the plane of the vibratory energy is constant.

131. The system of claim 104, wherein the expandable tubular member comprises a welbore casing.

132. The system of claim 104, wherein the expandable tubular member comprises a pipeline.

133. The system of claim 104, wherein the expandable tubular member comprises a structural support.

134. The system of claim 104, further comprising:
means for injecting vibratory energy into the expandable tubular member and the expansion device.

135. The system of claim 122, wherein one of the planes is longitudinal; and wherein another one of the planes is radial.

136. The system of claim 104, further comprising:
means for injecting vibratory energy into the expansion device to impart rotation to the expansion device.

137. The system of claim 104, further comprising:

means for reducing the required radial expansion forces during the radial expansion and plastic deformation of the expandable tubular member.

138. The system of claim 104, wherein means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device, comprises:

means for impacting the expandable tubular member.

139. The system of claim 104, wherein means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device, comprises:

means for impacting the expansion device.

140. The system of claim 104, further comprising:

means for rotating the expansion device during the radial expansion and plastic deformation of the expandable tubular member.

141. The system of claim 104, further comprising:

means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device from a location within the radially expanded and plastically deformed portion of the expandable tubular member.

142. The system of claim 104, further comprising:

means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device from a location within the expansion device.

143. The system of claim 104, further comprising:

means for increasing the plasticity and formability of the expandable tubular before the radial expansion and plastic deformation of the expandable tubular member.

144. The system of claim 104, further comprising:

means for increasing the plasticity and formability of the expandable tubular during the radial expansion and plastic deformation of the expandable tubular member.

145. The system of claim 104, further comprising:

means for injecting vibratory energy into one or more of the expansion device and the expandable tubular member, wherein the injected vibratory energy is provided in an initial plane, has an initial center frequency, and has an initial amplitude; and

means for during the radial expansion and plastic deformation of the expandable tubular member:

a) means for incrementing at least one of the plane, center frequency, and amplitude for the injected vibratory energy;

b) means for monitoring the amount of energy required to continue the radial expansion and plastic deformation of the expandable tubular member; and

c) means for repeating steps a) and b) until the completion of the radial expansion and plastic deformation of the expandable tubular member.

146. The system of claim 104, further comprising:

means for injecting vibratory energy into one or more of the expansion device and the expandable tubular member, wherein the injected vibratory energy is provided in an initial plane, has an initial center frequency, and has an initial amplitude; and

means for during the radial expansion and plastic deformation of the expandable tubular member:

a) means for incrementing two or more of the plane, center frequency, and amplitude for the injected vibratory energy;

b) means for monitoring the amount of energy required to continue the radial expansion and plastic deformation of the expandable tubular member; and

c) means for repeating steps a) and b) until the completion of the radial expansion and plastic deformation of the expandable tubular member.

147. The system of claim 104, further comprising:

wherein means for injecting vibratory energy into at least one of the expandable tubular member and the expansion device comprises: injecting fluidic materials into the expandable tubular member.

148. The system of claim 104, wherein the vibratory energy comprises vibratory energy in one or more planes; and wherein the vibratory energy comprises vibratory energy having a frequency distribution having one or more center frequencies.

149. The system of claim 104, wherein the vibratory energy comprises vibratory energy in a plurality of planes; and wherein the vibratory energy comprises vibratory energy having a frequency distribution having one or more center frequencies.

150. The system of claim 104, wherein the vibratory energy comprises vibratory energy having a frequency distribution having one or more center frequencies.

151. The system of claim 104, wherein the expandable tubular member comprises a pipeline.

152. The system of claim 104, wherein the vibratory energy comprises vibratory energy in a plurality of planes; wherein one of the planes is longitudinal; and wherein another one of the planes is radial.